of the Washington Agricultural College and School of Science. 'Relations of the Churches to State Colleges and Universities,' A. W. Harris, President of the University of Maine.

Section on Mechanic Arts: 'What Preparatory Work should be Required to enter Four-Year Engineering Degree Courses,' O. L. Waller, Professor of Mathematics and Civil Engineering of the Washington Agricultural College and School of Science. 'Engineering Standard in Land-Grant Colleges,' W. H. Williams, Professor of Mechanical Engineering and Mathematics of the Montana College of Agriculture and Mechanic Arts.

Section on Horticulture and Botany: 'Laboratory Methods in Teaching Horticulture,' L. C. Corbett, Professor of Horticulture of the West Virginia University. 'Relation of Rainfall to Fungus Diseases,' B. D. Halsted, Professor of Botany and Horticulture of Rutgers Scientific School. 'Testing of Fruits by the Experiment Stations,' S. M. Emery, Director of the Montana Agricultural Experiment Station. 'Technical Training in Teaching Horticulture,' S. B. Green, Professor of Horticulture of the University of Minnesota. 'Preliminary Report of the Committee for the Testing of Races of Peaches,' R. H. Price, Professor of Horticulture, Botany and Entomology of the State Agricultural and Mechanical College of Texas

Section on Entomology: 'Entomology in Agricultural Colleges,' E. E. Faville, Professor of Horticulture and Entomology of Kansas State Agricultural College; S. A. Forbes, Professor of Zoology of the University of Illinois; H. Osborn, Professor of Zoology and Entomology of Iowa State College of Agriculture and Mechanic Arts; L. Bruner, Professor of Entomology of the University of Nebraska. 'A Fungus Disease of the San José Scale,' V. H. Lowe, Entomologist of the New York Agricultural Experiment Station. 'The Teaching Function of the Station Worker,' J. B. Smith, Professor of Entomology of Rutgers Scientific School. 'The Influence of Nature-Studies in Schools upon the Biology of the College Curriculum,' C. M. Weed, Professor of Zoology and Entomology of New Hampshire College of Agriculture and Mechanic Arts.

Section on Agriculture and Chemistry: 'Clover, Phosphates, and Wheat in Ohio,' W. I. Chamberlin, of Ohio. 'Productivity as affected by Tillage, I. P. Roberts, Director of Cornell University Agricultural Experiment Station. 'The Maintenance Ration of Cattle,' H. P. Armsby, Director of the Pennsylvania State College Agricultural Experiment Station. 'The Mission of the Agricultural and Mechanical Colleges and Stations from the Standpoint of the Agriculturist,' J. S. Newman, Professor of Agriculture of Clemson Agricultural College. 'Upon the Possibilities of drawing Erroneous Conclusions from Plant Soil Tests designed as Guides to the Economical Manurial Treatment of Soils, and to serve as a Basis for the Development of Reliable Chemical Methods for ascertaining their Requirements,' H. J. Wheeler, Chemist of the Rhode Island Agricultural Experiment Station. 'The Significance of Stock-Feeding Experiments,' C. F. Curtiss, Director of the Iowa Agricultural Experiment Station. 'Notes on Butter Tests of Cows, M. A. Scovell, Director of the Kentucky Agricultural Experiment Station.

A. C. True.

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THERMAL EFFICIENCY OF STEAM-ENGINES.

A committee of the British Institution of Civil Engineers, composed of recognized authorities, has recently made a report, now published by the Institution, on the above subject, in which is proposed a standard and consistent scientific scheme for the treatment of thermal and thermodynamic quantities in the discussion of the experimentally determined efficiencies of the steam-engine. It is so important a document that we give space to a somewhat liberal abstract and summary of the conclusions of the committee.*

An introduction by the Secretary, Captain H. R. Sankey, gives a technical definition of the 'steam-plant' and points out the differences, the wastes, which distinguish the ideal and the real heat-engines. These differences are illustrated by an exceedingly interesting and helpful diagram in which the energy-flow is traced from its source in the fire-box of the boiler through the boiler and its contents of steam and water, on the one hand, for use in the engine, and, on the other hand, to the chimney as a waste. It exhibits the methods, extent and character of the wastes of thermal, of dynamic and of thermodynamic

* Report of the Committee appointed to consider and report to the Council upon the subject of the Definition of a Standard of Thermal Efficiency.—London, Published by the Institution, 1898.

phenomena in the engine as well as at the boiler, and exemplifies the case by making the diagram a correct measure, drawn to scale, of the performance of a famous steam pumping engine.

All the required data for exhibition of this flow of the energies through a heat-engine are secured and recorded in every well conducted and complete engine-trial, and ample data are now available for its illustration. One of the best of recent reports upon the performance of the exceptionally economical Leavitt engine at the Louisville, Ky., water works has been diagrammed in this manner by Captain Sankey, to make clearly understood the principles and the facts involved in the discussion of the 'thermal efficiency of steam-engines,' by this committee of the British Institution of Civil Engineers. This diagram is here reproduced, from that report, published as above. In this instance, every known precaution against waste of heat has been taken, and all the conditions, thermal, thermodynamic and dynamic, are in unusual degree favorable to a high resultant efficiency. The case is, therefore, a very exceptionally good illustration of thermodynamic action, and the wastes are much smaller than are commonly observed in the operation of even good classes of steam-engine.

"The broad river of heat, generated by the burning coal on the grate, is shown flowing to and through every part of the apparatus, losing by radiation at every step, and finally emerging at the chimney, in a flow of heated air and gases, and at the condenser, in the circulating water discharged, and at the engine-shaft as useful work." All of this broad river of heat arises from a source within the fuel bed, flows through its delta of narrower channels, mainly to waste, and it all finally emerges into the great sea of heat, the external atmosphere, as thermal energy; even the useful work being sooner or later retransformed into heat by friction, whether of engine or of work performed by the machine. Were our diagram to give the further history of these flows of energy it would show a cycle in which the external currents circulate from the engine into the atmosphere, into potential forms, once more, by retransformation into the stored energy of chemical affinities, through the ever-active influence of vegetation, later to be possibly again employed in other heat-engine cycles, when once more resurrected as potential energy of fuel.*

The diagram here reproduced is drawn to a scale, and quantities of heat, and temperatures as well, are shown at each step in the progress of the heat flow, from fuel to outer atmosphere and to the drainage channels of the country. The following verbal description may properly accompany the graphic story:

At the start, 183,600 B. T. U. per minute is the measure of the energy liberated in active form from its original, potential, condition in the fuel. Of this energy, 131,700 B. T. U. pass into the water and steam and are there stored as thermal energy, available for thermodynamic operations; 41,900 go toward chimney and economizer; 10,000 flow out of the system, as waste, through condition and radiation in the flow between boiler and economizer, 5,000 more at the economizer, and 15,750 are taken into the feed-water within the economizer and thus utilized. The balance, 20,150, get through the economizer and flow up chimney and thus into the outer air and are lost to the thermodamic system.

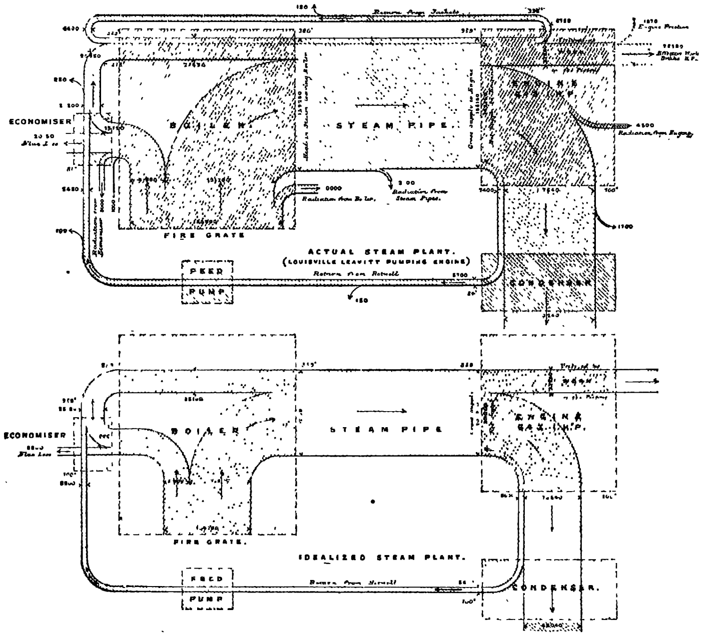
The economizer receives 5,450 B. T. U. from the feed-water coming from the engine and 15,750 from the furnace-gases;

*For original data of the case here taken, see Trans. Am. Society Mechanical Engineers, Vol. XVI., *Engineering News*, December 13, 1894. Proc. Brit. Inst. C. E., 1898.

sending the total, 21,200, toward the boiler; for use there; losing, however, 250, *en route*, and giving up the remainder, 20,950, together with the heat of jacket-water, joining the stream at the boiler, to reduce the demand for and cost of fuel, by raising the temperature of the water to be converted into steam.

The flow to the engine from the boiler 27,260 / 142,150 = 0.15, fifteen per cent. This is called the 'Thermal Efficiency of the Engine,' perhaps more correctly *Thermodynamic Efficiency of the Engine*. The indicated power is reported as 643 H. P. and the demand for heat at the piston is thus 221 B. T. U. per I. H. P. per minute.

Engine-friction absorbs work to the equivalent of 1,870 B. T. U. per minute,



Losses and Transfers of Heat in Steam-power Plants.

begins with a stock of 169,350 B. T. U. per minute, but 3,100 are lost on the way by conduction and radiation and by leakage from the steam pipes, and the engine actually receives a balance of 156,150 B. T. U. per minute. Of this, 7,400 go back in the feed-water and 6,600 from the jackets, making the net supply 142,150 B. T. U. per minute.

Of this net supply, only 27,260 are reported to have been transformed into mechanical energy, to flow through the engine and perform work, useful or other. The efficiency of this operation is, therefore, but and this gives 25,390 B. T. U. as the equivalent of the net, usefully applied, work of the engine, and this gives us 237 B. T. U. per minute as the consumption of energy per D. H. P., a measure of the 'brake efficiency,' as it is sometimes called.

The second of the two figures here represented, on the lower portion of the plate, illustrates the ideal case, the ideal steam-engine delivering the same quantity of 'indicated' power, and differing from the real engine by operating in the 'Rankine Cycle,' and in exhibiting no wastes by clearance or friction, conduction or radiation—

a purely thermodynamic case. At the boiler, also, there are no losses by conduction or radiation and the flue-gases are reduced to the temperature of the steam in the boiler before discharge.

Of the total heat developed in the furnace, now only 104,200 B. T. U., the large proportion, 31,400, are still wasted by way of the chimney, since the gases must be sent out at least as hot as the boiler-steam. The quantity sent to the engine is 72,800, to which is added the saved heat from the economizer, here also assumed to be employed, 28,100 B. T. U. The engine receives, thus, a total of 100,900 B. T. U. per minute, of which 5,600 is returned by way of the feed-pipe, giving a net supply of 93,300 for the thermodynamic cycle. This amounts to 148 B. T. U. per I. H. P. per minute, equivalent to an efficiency of 0.285. The ideal thus demands but 0.67, two-thirds the heat-supply of the actual engine.

This graphical analysis has special interest in connection with the employment of the engine-trial data in the calorimetric analysis of Hirn for detection and measurement of thermodynamic and other defects of the actual engine cycle. Where the jacket is employed, it is to be understood that the process of the flow of heat from the jacket-steam into the wall of the engine-cylinder is a continuous and uniform operation; but that the method and rate of flow from metal to steam, within the cylinder, is irregular and its precise law unknown.

The work of the Committee results in the recommendation that the thermal economical value of steam-engines should be stated in thermal units per indicated horse-power. It takes the so-called Rankine standard cycle—a thermodynamic cycle with isothermals as upper and lower limiting boundaries and with complete adibatic expansion and without clearance of compression—as the standard of comparison, the unit of thermodynamic efficiency with which to compare the efficiency of the real engine, and describes the method of testing and recording results of test and the forms of computation required in affecting this comparison of the ideal with the real case.

The ideal, Rankine, cycle was first proposed by that writer in 1854 in a paper published in Transactions Royal Society of Edinburgh, as of date of January 19, 1854. The paper was reproduced in the 'Miscellaneous Papers of Rankine,' page 400, section 46. Clausius described the same cycle in Poggendorff's Annalen, 1856, and later in his 'Mechanical Theory of Heat,' quite independently, however, of Rankine, of whose work he was at the time unaware.*

The following are the summarized recommendations of this committee, and it is recommended by them that authors presenting papers to the British Institution of Civil Engineers be invited to conform to these suggestions:

(1) That 'thermal efficiency' as applied to any heat-engine should mean the ratio between the heat utilized as work on the piston by that engine and the heat supplied to it.

(2) That the heat utilized be obtained by measuring the indicator diagrams in the usual way.

(3) That in the case of a steam-engine the heat supplied be calculated as the total heat of the steam entering the engine less the water-heat of the same weight of water at the temperature of the engine exhaust, both quantities being reckoned from 32° F.

(4) That the temperature and pressure limits, both for saturated and heated steam, be as follows:

Upper limit: the temperature and pressure close to, but on the boiler side of the engine stop-valve, except for the purpose of caculating the standard of comparison in

* Hirst's Translation of Clausius, 1867, page 161. This note, however, does not appear in the German edition of 1876.

cases when the stop-valve is purposely used for reducing the pressure. In such cases the temperature of the steam at the reduced pressure shall be substituted. In the case of saturated steam the temperature corresponding to the pressure can be taken.

Lower limit: the temperature in the exhaust-pipe close to, but outside, the engine. The temperature corresponding to the pressure of the exhaust steam can be taken.

(5) That a standard steam-engine of comparison be adopted, and that it be the ideal steam-engine working on the Rankine cycle between the same temperature and pressure limits as the actual engine to be compared.

(6) That the ratio between the thermal efficiency of an actual engine and the thermal efficiency of the corresponding standard steam-engine of comparison be called the efficiency ratio.

(7) That it is desirable to state the thermal economy of a steam-engine in terms of the thermal units required per minute per Indicated HP., and that, when possible, the thermal units required per minute per Brake HP. be also stated.

(8) That, for scientific purposes, there be also stated the thermal units required per minute per HP. by the standard engine of comparison, which can readily be obtained from a diagram similar to that given, and from which the efficiency ratio can be deduced.

R. H. THURSTON.

THE KINETIC THEORY OF GASES AND SOME OF ITS CONSEQUENCES.*

THOUGH Science—Science with a capital S—is often contrasted with Art—Art with a capital A; though the former is held to be dry and unattractive, while the latter stirs the imagination and arouses 'thoughts that breathe and words that burn;' yet the follower of science now and then is rewarded for his toil by an ordered sequence which appeals to the imaginative side of his nature, no less than the rhythmic harmony of poetry, or the measured cadences of music. Indeed, it is not impossible for the poet to express better than, and as truly as in the pages of the *Philosophical Transactions*, the highest generalizations of science. In this Tennyson stands unrivalled. Take, for example, the stanzas:

"There rolls the deep where grew the tree,
O earth, what changes hast thou seen!
There where the long street roars, hath been
The stillness of the central sea.

"The hills are shadows, and they flow
From form to form, and nothing stands;
They melt like mist, the solid lands,
Like clouds they shape themselves and go."

It contains an epitome of the whole of geology. The science is mere elaboration of the ideas contained in Tennyson's beautiful verses.

The difficulty in gaining the appreciation of the 'general public' is in presenting the ideas in intelligible language. That the scientific and the romantic are sometimes closely intermingled is indisputable; but the romance is one which appeals to few. In the following pages an attempt will be made to show how the thoughts of many men, each striving to 'increase natural knowledge,' as the formula of admission to the Royal Society runs, have led to a discovery of some interest—that of a hitherto unsuspected constituent of atmospheric air.

The Roman poet Lucretius, a friend and contemporary of Cicero, was the author of a poem entitled 'De Rerum Naturâ' ('On the Nature of Things'). In this poem, which treats of almost all things in heaven and earth, he argues that the atoms, the existence of which is obvious because one sees them in a cone of light passing through a dark room, fall rapidly together in their dancing course throughout the spheres,

* Reprinted from the *Contemporary Review* for November, 1898.